ONR Graduate Traineeship Award Update

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LONG-TERM GOALS

The top-level goal of this project is to examine the physics of ambient noise in the ocean which limits the use of ambient noise correlation techniques. In addition this research should lead the PI to a Ph.D.

OBJECTIVES

Noise correlation processing extracts coherent signals from seemingly random noise data. Although this technique has been successfully used in processing ocean ambient noise data it has severe limitations due to the changing ocean environment and the spatial and temporal variability in sources. In this project we are: (1) investigating the physics of the noise processing procedure that constrains the optimum correlation, (2) attempting to understand where and how the degradation of the derived time domain Green's function (TDGF) comes about, and (3) exploit array and signal processing techniques to optimize the signal-to-clutter (otherwise known as the 'signal-to-noise') rate of the noise correlation processing.

APPROACH

Using both computer simulations, Monte Carlo noise simulations, and ambient noise ocean data I have continued analyzing the noise correlation processing techniques already in use. In addition, I am continuing to adapt standard signal processing techniques (e.g. beamforming) to the noise correlation on a horizontal array. The data set used is from the Adaptive Beach Monitoring (ABM) experiment in 1995. The simulation is of the same ocean environment so the comparison between the results is easy.

This work was greatly aided by my advisor, Professor William Kuperman, and Prof. Karim Sabra (formerly of MPL, now at Georgia Tech). Prof. Sabra had previously laid much of the groundwork for this research and allowed me to build upon his suite of noise processing models.

WORK COMPLETED

The primary focus of this year's work was adapting acoustic array processing techniques (i.e. beamforming) to the noise correlation processing. Planewave beamforming the ambient noise record on two arrays before correlating enhanced the individual travel paths between the arrays. In the case of the dataset used in this research, a direct path and a surface reflection path between the arrays were individually resolved using significantly less time in the correlation.

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RESULTS

Incorporating beamforming in the noise correlation processing of ocean ambient noise allowed for the extraction of environmental information while significantly reducing the amount of time needed for the correlation. The use of small arrays instead of averaging individual correlations between hydrophones significantly reduced the residual correlation fluctuations due to irrelevant noise sources allowing the desired arrival time information to be more quickly extracted.

Figure 1 shows four plots comparing the signal to noise ratio (SNR) for the beamformed correlation between two arrays of various sizes set at increasing distances apart. A minimum SNR for extracting the correlation function information (shown with a black line) shows the improvement in the SNR of the correlation processing due to increasing the number of elements in each array in the beamforming. The SNR is defined here as the strength of the beamformed correlation signal at the expected arrival time divided by the standard deviation of the residual fluctuations of the correlation.
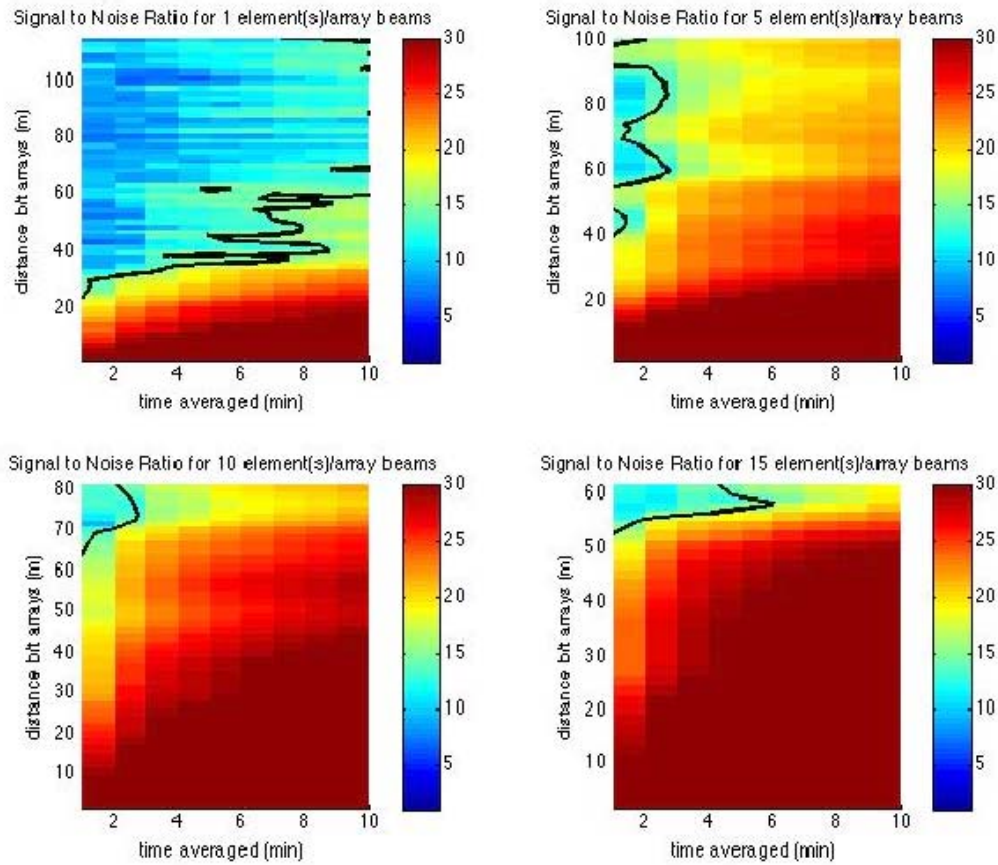
Figure 1: Comparison of the normalized SNR for the direct path arrival between two arrays. In each colorplot above the x-axis is the number of minutes of ambient noise data averaged in the noise correlation, the y-axis is the distance (in meters) between two arrays, and the color is the SNR measured in dB. The number of hydrophone elements on each array is: upper left - 1, upper right - 5, lower left - 10, lower right - 15. The solid black line denotes 15dB SNR, representing a minimum value needed to resolve the peak in the correlation.

Incorporating planewave beamforming in the correlation processor to look for the surface reflections gives peaks at distinct surface reflections. Figure 2 shows an example of this using the ambient ocean noise data (top plot) and a Monte Carlo noise model simulation (bottom plot). The white Xs on each plot show the theoretical arrival time and incoming angles for various surface reflections (single bounce, two bounces, etc) given the measured (for the data) or modeled (for the simulation) environment. The large, spread out initial peak is the direct path signal. The secondary peak at ~ .06 seconds and 27 degree arrival is consistent with a surface reflection path between bottom mounted arrays ~82.5m apart in a 21m depth channel.
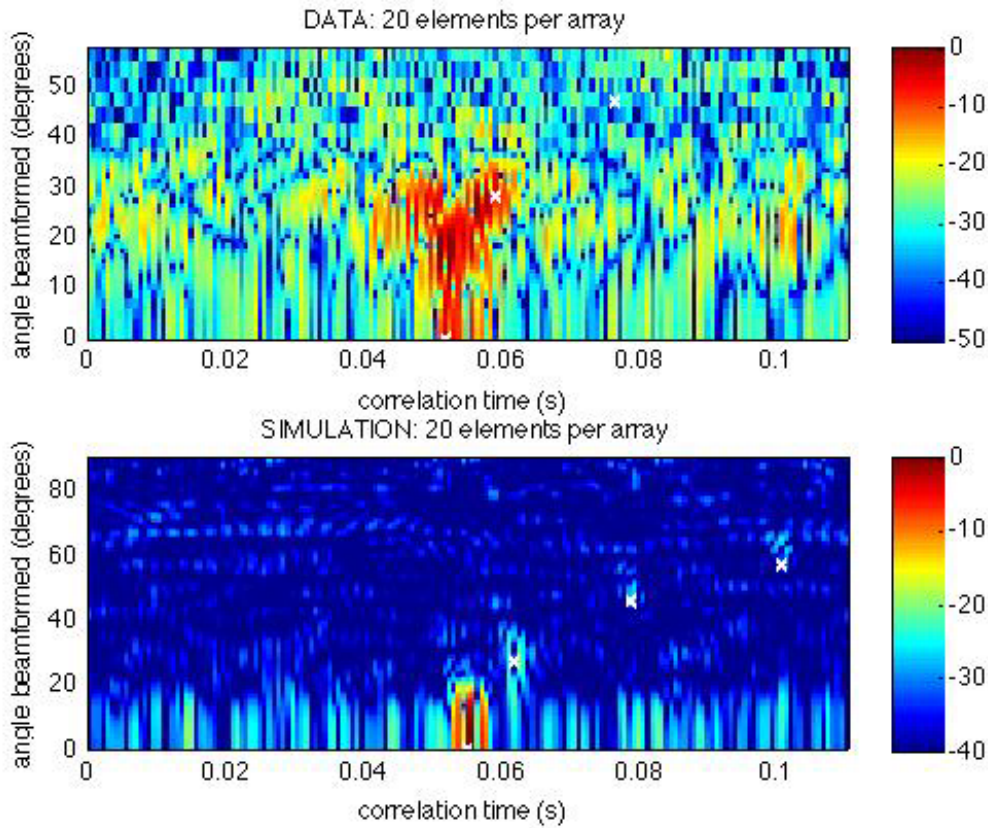
Figure 2: Results of planewave beamforming incorporated in the noise correlation processor. In both plots the x-axis is the correlation time in seconds, the y-axis is the angle beamformed in degrees, and the color is the intensity in normalized dB. The top plot is made using ambient ocean noise data, the bottom plot is made using Monte Carlo noise model simulation of the same environment. The white Xs represent the expected raypath arrival times and angles for the surface reflection paths between the two 20 element arrays used.

IMPACT/APPLICATIONS

Potential future impact for Science and/or Systems Applications is that it finds application for noise, typically rejected and not further used.

RELATED PROJECTS

This research is related to the ONR 6.1 program "Extracting Coherent Structures from High Frequency Ocean Noise."